Susceptibility to unconscious influences is unaffected by a challenging inhibitory task or mental exhaustion

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Susceptibility to Unconscious Influences is Unaffected by a Challenging Inhibitory Task or Mental Exhaustion

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Abstract

Unconscious influences have been demonstrated in a variety of behavioural contexts, however, a key question remains – to what extent do such influences vary with our changing mental states? We examine whether a prior inhibitory challenge increases susceptibility to subliminal priming in a stem completion task employing neutral (Experiment 1) and reward salient terms (Experiment 2). Results show stem completions to be significantly influenced by unconscious priming, and the challenging inhibitory task (the Stroop) to be significantly more mentally exhausting than the control task. However, neither the degree of inhibitory challenge, trait self-control, nor task-related mental exhaustion significantly influenced unconscious priming. Bayesian analysis provides strong evidence that prior inhibitory challenge does not affect susceptibility to unconscious priming. The study supports the conclusion that unconscious processing can be independent of consciously experienced mental states and provides reassurance that inhibitory impairment, common to mood disorders, should not increase susceptibility to unconscious influences.

Keywords: Inhibitory control; self-control; unconscious; subliminal priming

1. Introduction

Human susceptibility to unconscious influences has been of enduring interest in both lay and research contexts since the earliest psychological endeavours. An extensive literature exists demonstrating the effects of unconscious priming in various forms on a variety of behavioural outcomes (e.g. Kiefer, 2002; Klauer, Eder, Greenwald, & Abrams, 2007). An important question that is largely unexplored in this context however, is the extent to which such influences vary with our changing mental state – are we more susceptible to unconscious influences when tired or exhausted from prior mental exertion? Gauging the extent of such variations could be especially important to understanding how unconscious influences contribute in a variety of clinical conditions characterised by chronic mental fatigue and impaired inhibitory control. Those with low levels of self-control suffer from poorer inhibition of negative emotional responses (Kieras, Tobin, Graziano, & Rothbart, 2005), engage in more health risk behaviours (Wills, Isasi, Mendoza, & Ainette, 2007) and report higher levels of psychopathological symptoms including those linked to depression, anxiety, obsessive-compulsive disorder, phobias and paranoia (Tangney, Baumeister, & Boone, 2004), see de Ridder, Lensvelt-Mulders, Finkenauer, Stok, and Baumeister (2011) for a meta-analysis. Thus, with control being paramount to a healthy human psyche, it is important to better understand how those suffering from mental fatigue might be differentially affected by unconscious influences.

Hypnotism and evolutionary theory are often credited as being the first allusions to the unconscious, but it was Pierce and Jastrow (1884) who were the first to empirically study subliminal perception and to report the ability to distinguish between different stimuli, even in the absence of conscious awareness. Another early account of subliminal priming comes from Sidis (1898), who presented participants with small cards printed with a single number or letter, at a distance from which they reported being unable to decipher the stimuli. Despite

reporting being unable to consciously perceive the stimuli, Sidis discovered that when tested using a forced choice paradigm, the participants guessed the cards' contents correctly at above chance, suggesting some level of unconscious perception. Although it became a popular topic of research (see Adams, 1957, for a review), subliminal priming received much criticism from claims that there was a need for a higher level of certainty about participants' awareness of primes or the implementation of a confidence criterion (Eriksen, 1960).

Cheesman and Merikle (1984, 1986) distinguished between objective and subjective thresholds of conscious awareness. The objective threshold is defined by the level at which performance in some discrimination is objectively at chance. In contrast, the subjective threshold more directly taps the phenomenal experience and is defined by that level at which participants believe they are unable to discriminate the stimuli regardless of whether they actually show above chance accuracy (Jack & Shallice, 2001; Merikle, Smilek, & Eastwood, 2001). The subjective threshold demonstrates a lack of meta knowledge in the sense that participants either truly believe they are guessing or show no correlation between their confidence and accuracy, referred to respectively as the 'guessing criterion' and 'zero correlation criterion', (Dienes, Altmann, Kwan, & Goode, 1995). There has been considerable evidence for priming below the objective threshold, however for the most part effects have been smaller, hard to attain and short lived (e.g. Draine & Greenwald, 1998; Klauer et al., 2007, though cf. Van den Bussche, Van den Noortgate, & Reynvoet, 2009, for a meta-analysis of subliminal priming effects who report no significant effect of using objective versus subjective thresholds). In the present study, where the central purpose is to assess whether different mental states might affect our susceptibility to unconscious influences, it is important that we attempt to adopt the most sensitive of measures; for this reason, we adopt a subjective threshold in identifying participants unconscious thresholds.

One of the enduring paradigms for the study of unconscious influences, is the stem completion task (see Graf & Mandler, 1984). This task involves presenting a word prime for a duration too brief to be consciously discerned and then requiring the participant to complete three letters (a word stem) to form the first word that comes to mind. Typically, the word stem could be completed to form the subliminally presented word as well as multiple alternatives. For example, for the prime 'reliable', the stem would be 'rel' and possible completions would include 'reliable', 'relevant', 'relax' etc. Valid inferences from a stem completion task clearly depend on each stem having an appropriate minimum number of alternate completions (Soler, Dasí, & Ruiz, 2015). Studies have consistently demonstrated that when participants report being unable to read the prime i.e. it is below their subjective threshold, it nonetheless influences their subsequent choice of word completion (Perrig & Eckstein, 2005; Tiggemann, Hargreaves, Polivy, & McFarlane, 2004). The stem completion paradigm has been employed extensively to study implicit learning (Fleischman et al., 2005), lexical memory (Nelson, Keelean, & Negrao, 1989) and memory related individual differences (Lorenzi, Giunta, & Di Stefano, 2006). The present study exploits the stem completion task to index how the degree of subliminal priming differs across task conditions.

When exploring the potential effect of mental states on susceptibility to unconscious influences, a relevant literature is that which has sought to examine the effect of mental exertion on conscious behaviours. This has predominantly been explored in the context of research seeking to manipulate self-control. Such research has employed a dual-task paradigm to evaluate the extent to which exerting inhibitory control on an initial task affects the degree of control applied to subsequent tasks. Prior inhibitory tasks have been reported to influence subsequent behaviour in a variety of different ways, for example resulting in overeating (Hofmann, Rauch, & Gawronski, 2007; Vohs & Heatherton, 2000), increased risk-taking (Fischer, Kastenmüller, & Asal, 2012), aggression (DeWall, Baumeister, Stillman, &

Gailliot, 2007), impulse buying (Vohs & Faber, 2007), and more frequent stereotypical judgments (Govorun & Payne, 2006), see Hagger, Wood, Stiff, and Chatzisarantis (2010), for a meta-analysis.

Some accounts of the effects of mental exhaustion on subsequent behaviour have proven to be controversial, with the resource model (Baumeister, Bratslavsky, Muraven, & Tice, 1998) having been especially subject to challenge. This model proposes a reliance on a limited pool of resources which is depletable with use and, once used, takes time to replenish (Baumeister & Vohs, 2007). When in this depleted state subsequent attempts at self-control are thought to be impaired (Baumeister et al., 1998). However, attempts to characterise the resource as blood glucose (Gailliot, Plant, Butz, & Baumeister, 2007; Masicampo & Baumeister, 2008) have been vigorously challenged (Beedie & Lane, 2012; Job, Dweck, & Walton, 2010; Kurzban, 2010; Martijn, Tenbult, Merckelbach, Dreezens, & de Vries, 2002; Schmeichel & Vohs, 2009; Tice, Baumeister, Shmueli, & Muraven, 2007) and without an identifiable resource the model is of limited theoretical value (Kurzban, Duckworth, Kable, & Myers, 2013). A recent meta-analysis (Carter, Kofler, Forster, & McCullough, 2015) and a registered replication report (Hagger et al., 2016) also further challenge this conceptualisation. Nevertheless, new research has demonstrated that as long as inhibitory control tasks, such as those employed in the self-control literature (e.g. the colour naming Stroop), are experienced as being more mentally exhausting, they do appear to impact upon further attempts at self-control (Dang, 2017). The Stroop task was identified by Dang as amongst the strongest and most reliable of the self-control tasks used to induce a state of mental exhaustion and is therefore adopted in the present study as our inhibitory control manipulation.

Despite the enduring belief that trait levels of self-control protect, and are positively correlated with, an individual's ability to overcome the depleting effects of prior exertion of self-control (Gillebaart & de Ridder, 2015; Muraven, Collins, Shiffman, & Paty, 2005), some studies have reported a negative correlation between the two (Imhoff, Schmidt, & Gerstenberg, 2014) or have failed to find any effect at all (Stillman, Tice, Finchman, & Lambert, 2009). Therefore, in order to further explore and control for any relationship between trait levels of self-control, and the use of inhibitory control processes during periods of mental fatigue, we include the Self-Control Scale (Tangney, Baumeister, & Boone, 2004) in the present study. In spite of the challenges encountered by attempts to model self-control, interesting questions remain regarding the effect of mental exhaustion on subsequent unconscious processing.

A large body of research indicates that when adequate cognitive capacity is available, behaviour will be predominantly driven by explicit and controlled processes. However, in situations where this capacity is unavailable, behaviour will be driven by impulses, attitudes, and implicit response tendencies (Hofmann et al., 2007), as the lack of cognitive capacity leads to an inability to inhibit such responses and a reliance on automatic bottom-up processing (Bertrams, Baumeister, Englert, & Furley, 2015). Indeed, whilst perceiving, storing, and retrieving information appears to happen automatically (Schmeichel, Vohs, & Baumeister, 2003), inhibiting responses appears to decrease mental efficiency on subsequent executive functions such as reading comprehension, working memory and response inhibition (Stucke & Baumeister, 2006). This switch to automatic implicit response tendencies is notably demonstrated in studies employing Implicit Association Tests which have shown that after completing a demanding inhibitory control task, participants are more likely to be guided by their automatic attitudes and make more stereotype consistent errors on racial discrimination tasks (e.g. Govorun & Payne, 2006). Furthermore, in a colour priming study,

Bertrams et al., (2015) demonstrated that those who had previously completed a task high, versus low, in the need for self-control were more susceptible to the negative effect of being primed with the colour red. Specifically, participants completed one of two versions of a writing task that involved either directly copying some text or reproducing it with specific changes such as omitting the letter e and including deliberate misspellings. They were then primed with the word 'test' on either a red or grey background prior to completing a mental arithmetic evaluation. The red colour priming effect of decreased arithmetic performance was only seen for those who had previously exerted high levels of inhibitory control. However, the approach adopted by Bertrams et al., utilised consciously presented colour blocks as their priming methodology. As such, findings from the study cannot be conclusively attributed to unconscious influences.

Understanding whether mental fatigue increases our susceptibility to unconscious influences is important from a theoretical standpoint and has potentially important practical implications. In the present study, we specifically examine unconscious priming achieved through subliminal word presentation. Here we examine whether the effects observed in conscious contexts extend to unconscious influences. Specifically, we test for the first time whether a prior inhibitory challenge increases susceptibility to unconscious priming and whether this varies with the emotional salience of primes. The degree of prior inhibitory challenge is manipulated by the completion of either an easy or difficult version of a colour classification task, the Stroop task. The effect of this manipulation is then examined on the extent to which unconscious priming influences responses in a stem completion task. Experiment 1 examines how a prior inhibitory challenge effects the priming for neutral terms. Experiment 2 then contrasts the effect for neutral and reward salient terms i.e. those relating to food and drink. If a challenging inhibitory task increases subsequent susceptibility to

unconscious influences, then those in the challenging task condition would be expected to complete a larger proportion of the stems with the subliminally primed target words.

2. Experiment 1

2.1 Method

2.1.1 Participants

Participants were 60 volunteers (33 female, 27 male) aged 18-29 years (*M* = 20.75, *SE* = 1.79) recruited from the University of Sussex and participating in exchange for entry into a £25 prize draw. Participants were naïve to the experimental hypothesis and were randomly assigned in equal proportions to one of two inhibitory task conditions: inhibitory challenge vs. control. All participants were native English speakers. This and the subsequent experiment received ethical approval from the University of Sussex School of Psychology ethics committee.

2.1.2 Materials

The controlling program was implemented in Matlab, run on a Pavilion DM4 computer with a 15" 60Hz monitor. Participants were seated with a viewing distance of 600mm. The complete set of materials for both experiments and the corresponding data has been made publicly available on the Open Science Framework (OSF) and can be retrieved from https://osf.io/gphkq/.

The threshold finding task and stem completion task used distinct sets of words. The threshold finding task used ten colour names and the numbers one to twenty. These highly familiar words were used on the basis that the threshold for their detection would be lower than that for the less familiar terms used in the stem-completion task. The stem completion task utilised a list of 100 target words compiled from the British National Corpus online service. No two words began with the same three letters and these three letter stems (e.g.

'bis' for 'biscuit') had at least two possible alternative real word completions (e.g. bishop or bisect). Non-words for both the threshold finding task and stem completion task consisted of random sequences of consonants, matched in length to the target words. See Appendix A for a full list of the word stimuli used in the experiment. Words and non-words were displayed in 'Courier New' font size 30 and were light grey (0.8 on a scale of 0-1 where 0 = black and 1 = white), with a luminance of 63.78 cd/m^2 and contrast of -0.36, presented on a white background with a luminance of 99.68 cd/m^2. The mask was 40 by 180 mm (large enough to obscure the largest word used) and comprised randomized patterns of black and white 3-pixel by 3-pixel blocks. Masks had a maximum luminance of 99.68 cd/m^2, a minimum luminance of 0.09 cd/m^2 and a contrast of -0.99.

The full 36 item Self-Control Scale (SCS; Tangney et al., 2004) was included as a self-report measure of trait self-control.

2.1.3 Design

The experiment utilised a mixed design with two independent variables: inhibitory task (between subject: challenge vs. control) and priming (within subject: target word vs. non-word). The primary dependent variable was the number of stems completed with the target word. The measure of trait self-control provided by the SCS was included as a covariate.

2.1.4 Procedure

The experiment was conducted in a quiet room with the experimenter present at all times. All instructions were given on screen and clarification was provided by the experimenter when required. Participants provided demographic information (age and gender) before beginning the experimental tasks. Each of the experimental tasks, in the order they were completed, are outlined below.

Visual threshold task. This established individual visual thresholds in order to ascertain that primes in the stem completion task were presented below the subjective threshold of conscious awareness. Each trial involved the presentation of a word or non-word with every four trials including two of each in random order. Trials began with a fixation cross presented in the centre of the screen for 1000ms. The black and white mask then appeared in the centre of the screen for 600ms. The target was then presented for the same duration before the mask was again presented for a further 600ms. Participants were then presented the question 'Do you think there was a real word or a non-word?' and their response captured using the arrow keys. A second question, 'Do you have any confidence in your judgement?' alongside the options 'some confidence' and 'guess', was then displayed. They were instructed to indicate having 'some confidence' even if they had only the tiniest amount.

Initially, every trial correctly classified and made with 'some confidence' resulted in a 50ms reduction in the duration that the target was presented on subsequent trials (the mask duration of 600ms remained unchanged throughout). These reductions continued until the participant reported 'guessing', after which the duration of exposure was increased to that of the previous trial and the subsequent reductions after correct confident trials reduced to 16.67ms (a single screen refresh). Hence, the subjective unconscious threshold was always approached in steps of a single screen refresh. When participants reported that they were guessing for 6 consecutive trials at the same exposure duration that duration was taken to be their subjective unconscious threshold and the task ended.

Inhibitory control manipulation. Participants completed one of two versions of a colour naming task (inhibitory challenge vs. control). Those in the inhibitory challenge condition completed a four-colour Stroop task requiring them to classify the colour in which one of the words red, blue, green or yellow were written while suppressing the tendency to

respond based on the word itself. For example, 'red' written in blue was to be classified as blue and not red (the four text colours used were also red, green, blue and yellow). Participants were instructed to be as accurate as possible and keep errors to an absolute minimum. Each trial began with a fixation cross for 300ms before the colour word was presented for 1000ms. Words were displayed in 'Arial' font size 50. Classifications were made using the number keys 1-4 with their corresponding colours shown onscreen in monochrome. If participants failed to respond within one second or a wrong classification was made, then an error tone (middle C pitch) sounded. Every eight trials contained two trials of each colour word in a randomized order, with a total of 240 trials. For six out of every eight trials the colour word and the text in which it was written were the same (concordant trials), for the remainder the colour words were written in one of the other three colours chosen at random (discordant trials).

Those in the control group completed a simplified colour classification task that did not require any inhibition. Specifically, only two colour words were presented (red and green) and the text colour was always congruent with the word. No time limit was imposed however the error tone still sounded if a mistake was made. The duration of the control condition was fixed to match that of the inhibitory challenge condition, irrespective of the number of trials completed. The colour classification task was followed by a 1-minute break during which a countdown timer was presented on-screen.

Stem completion task. For each participant, the primes consisted of a randomly selected 50 of the 100 target words together with the length-matched non-words for the other 50 target words. The order of word and non-word trials was randomised over participants. Each trial consisted of the following: a fixation cross presented in the centre of the screen for 1000ms, followed by a forward mask for 600ms, followed by the word or non-word prime for the individual's threshold duration, followed by a backward mask for 600ms. A question

mark then appeared in the centre of the screen to which participants had to respond either 'Y' for yes if they thought they had seen the prime or 'N' for no if they did not. Where the participant responded with 'Y' they were presented with a screen prompting them to type in what they believed they saw and to press enter to move to the next trial; note no stem completion was conducted where they believed they had seen a prime. Where the participant responded with 'Y' and correctly identified the prime, then the prime exposure duration was reduced by 16.67ms for subsequent trials. If the participant chose 'N' they were given the 3-letter stem corresponding to the target word with the instruction to complete it with the first word that came to mind. Participants were given 10 seconds to respond before a warning tone was played and a message to please hurry presented on-screen. Participants were encouraged to report any targets they thought they saw and incentivised to do so by the provision of a bonus for any correctly identified. Thresholds ranged from 85 to 187ms (M = 131.33ms, SE = 3.19ms). A complete list of individual thresholds can be found in the data file provided on the OSF.

Rating of mental exhaustion. A single screen was displayed with the question 'Thinking back to the earlier colour classification task, how mentally exhausting did you find it?' Responses were recorded on a VAS scale ranging from 'Not at all' (1) to 'Extremely' (600).

Self-control questionnaire. Finally, participants completed the Self-control Scale using keys 1 to 5 on the keyboard to correspond to the five-point Likert scale ranging from 1 ('not at all') to 5 ('very much').

2.2 Results

2.2.1 Inhibitory Control Induced Mental Exhaustion

An independent t-test revealed that participants in the inhibitory challenge condition rated the inhibitory task as significantly more mentally exhausting (M = 369.20, SE = 23.53)

than those in the control condition (M = 198.03, SE = 31.94), $t(51.89) = -4.31$, $p < .001$, d = 1.13.

2.2.2 The Effect of a Prior Inhibitory Control Challenge on Unconscious Priming

A 2 (inhibitory task: challenge vs. control) x 2 (priming: word vs. non-word) mixed ANOVA was conducted on the percentage of stem completions that matched the target word (target matches), see Figure 1. The analysis revealed a significant main effect of priming, $F(1, 58) = 6.43$, $p = .014$, $\eta_p^2 = 0.10$, no significant main effect of inhibitory task, $F < 1$, and no significant interaction, $F < 1$. The effect of priming reflected a significantly greater number of target matches for the word versus the non-word priming condition.

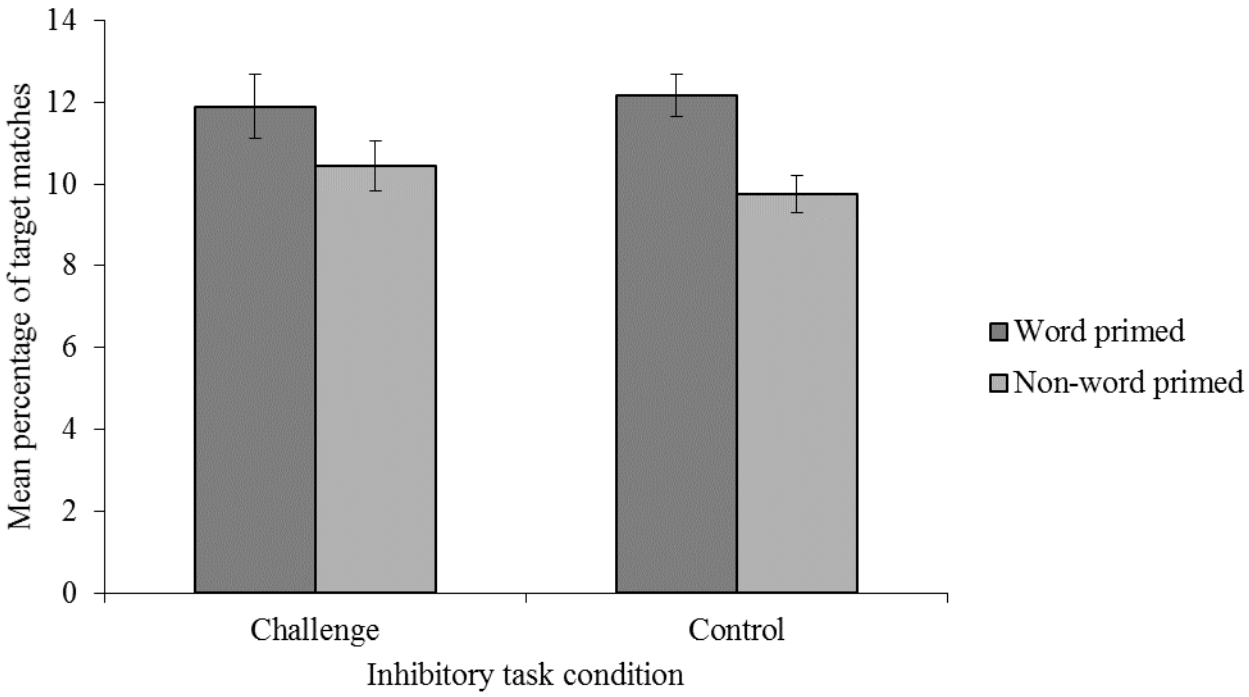

Figure 1. Mean percentage of stem completions that matched the target word by priming and inhibitory task condition (+/- 1 SEM)

A Bayes analysis on the effect of the inhibitory task was conducted to establish the extent to which this data provides evidence for the null hypothesis, namely that a prior inhibitory challenge has no effect on susceptibility to unconscious priming. Adopting the procedure advocated by Dienes (2014), we specified the prior as a uniform distribution from zero to twice the effect observed in the control condition. The resulting Bayes factor of 0.25 is less than one third and thus represents strong evidence for the null hypothesis.

2.2.3 The Effect of Trait Self-Control and Mental Exhaustion on Unconscious Priming

To evaluate the potential effects of trait self-control and mental exhaustion on unconscious priming the above ANOVA was repeated with SCS and reported task-related mental exhaustion included as covariates. Neither covariate achieved significance, all $F < 1$.

2.3 Discussion

Experiment 1 aimed to investigate the effect of a prior inhibitory task on subsequent susceptibility to unconscious priming using a stem completion paradigm. Consistent with the established literature (Perrig & Eckstein, 2005; Tiggemann et al., 2004) the stem completion task revealed a significant sensitivity to unconscious priming. The inhibitory task was also rated by participants to be significantly more mentally exhausting than the control task, suggesting that it was successful in creating greater inhibitory demand. However, the prior inhibitory challenge was not found to influence the degree of susceptibility to unconscious priming, with a Bayes analysis indicating that this was a sensitive null result. Similarly, neither trait self-control nor task-related mental exhaustion were found to significantly influence unconscious priming.

Our findings contrast with those of previous studies examining the effects of prior inhibitory challenge on responsiveness to consciously perceived environmental cues (Govorun & Payne, 2006). However, aside from the fact that the cues were presented consciously, these studies predominantly examined the response to emotional or reward

salient items, such as food and drink (e.g. Papies & Hamstra, 2010; Papies et al., 2008). This highlights the possibility that our failure to observe an effect of the prior inhibitory challenge on unconscious priming may have been limited by our use of neutral terms. In Experiment 2 we sought to address this question directly by introducing a systematic difference in word type such that there were both reward salient and neutral terms. All other aspects of the study remain the same as Experiment 1, while the additional manipulation of word type permitted us to contrast the effect of a prior inhibitory task on unconscious priming for reward salient and neutral terms.

3. Experiment 2

3.1 Method

3.1.1 Participants

Participants were 120 volunteers (74 female, 46 male) aged 18 to 41 (M = 22.01, SE = 0.38) recruited from the University of Sussex and participating in exchange for entry into a £25 prize draw or 2 course credits. Participants were naïve to the experimental hypothesis and were randomly assigned in equal proportions to one of four between subject conditions created by a 2 (inhibitory task: challenge vs. control) x 2 (priming: target word vs. non-word) design.

3.1.2 Materials

All materials were identical to those of Experiment 1 except for the words used in the stem completion task, described here. Two word lists were generated from the British National Corpus online service; 50 reward salient words relating to food and drink, and 50 neutral words, see Appendix A. Reward salient and neutral words were matched for length and frequency of use in written English. As in Experiment 1, no two words began with the

same three letters and these three letter stems all had at least two possible alternative completions in the English language.

3.1.3 Design

The experiment exploited a mixed design with three independent variables: Inhibitory task (between subject: challenge vs. control), priming (between subject: word vs. non-word) and word type (within subject: reward salient vs. neutral). The primary dependent variable was the number of stems correctly completed to match the target word. The measure of trait self-control provided by the SCS was included as a covariate.

3.1.4 Procedure

The experimental procedure was the same as in Experiment 1 with the exception that priming was a between-subject condition rather than within-subject, and the primes included two categories of word (reward salient and neutral). This change was made in order to avoid increasing the total number for participants which could otherwise be a confounding factor. As such, participants were either primed with the target words on all 100 trials (word condition) or primed with paired random sequences of consonants (non-words) matched for target word length on all 100 trials (non-word condition). Thresholds for word and non-word stimuli ranged from 35 to 203ms (M = 103.69ms, SE = 2.79ms), with the complete list of individual thresholds available in the data file provided on the OSF.

3.2 Results

3.2.1 Exclusions

Normality checks revealed two extreme outliers; while their removal did not alter the observed pattern of significant effects they were excluded for the analyses reported below.

3.2.2 Inhibitory Control Induced Mental Exhaustion

An independent t-test revealed that participants in the inhibitory challenge condition rated the inhibitory task as significantly more mentally exhausting (M = 410.64, SE = 15.75)

than those in the control condition (M = 271.64, SE = 21.54), t(106.21) = 5.21, p < .001, d = 0.96.

3.2.3 The Effect of a Prior Inhibitory Challenge on Unconscious Priming

A 2 (inhibitory task: challenge vs. control) x 2 (priming: word vs. non-word) x 2 (word type: reward salient vs. neutral) mixed ANOVA was conducted on the percentage of stem completions that matched the target word (target matches), see Figure 2. The analysis revealed a significant main effect of priming, F(1, 114) = 5.33, p = .023, η_p^2 = .05, a significant main effect of word type, F(1, 114) = 348.03, p < .001, η_p^2 = .75, no significant main effect of inhibitory task, F < 1, and no significant interactions, all F < 1.

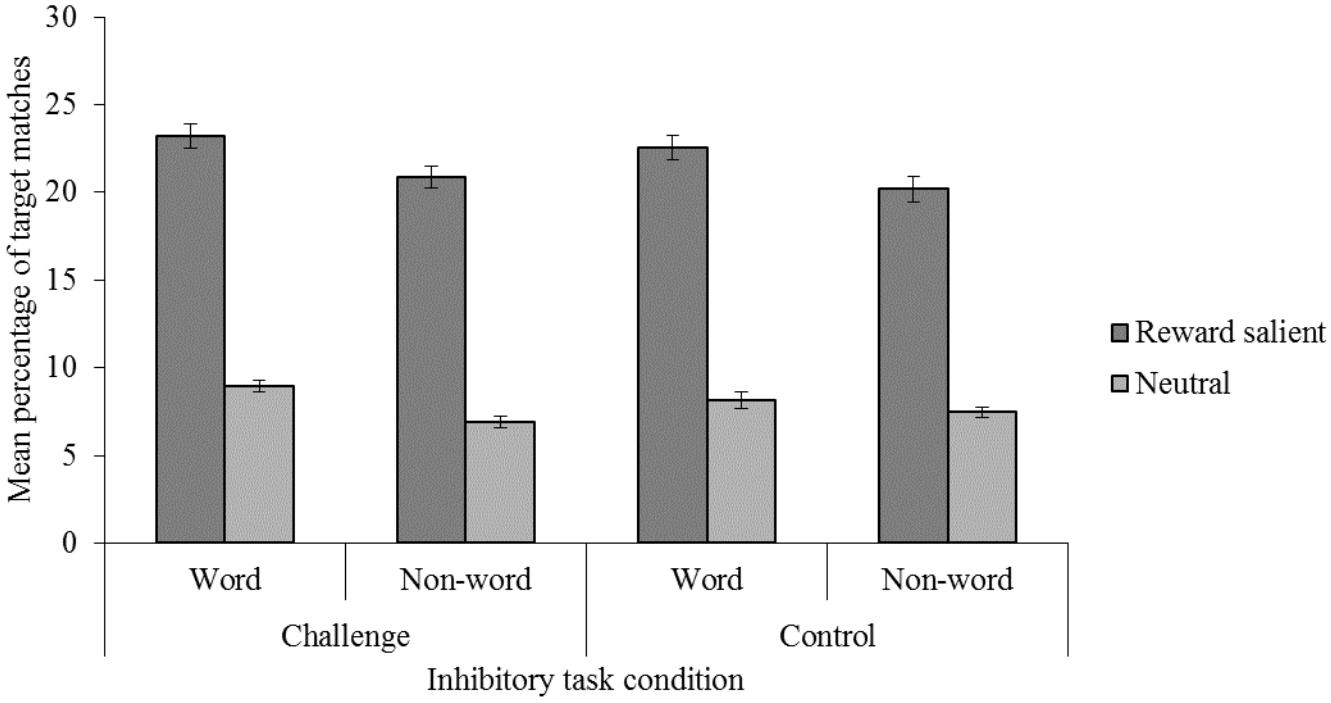

Figure 2. Mean percentage of stem completions that matched the target word by inhibitory task, priming, and word type conditions (+/-1 SEM).

Consistent with Experiment 1, the significant main effect of priming reflected a larger number of target matches for word primes versus non-word primes. The significant main

effect of word type indicates that participants were more likely to complete the word stems with reward salient terms than neutral terms. Crucially, again consistent with Experiment 1, the absence of a significant main effect or interaction involving the inhibitory task condition indicates that the inhibitory challenge failed to influence the degree of unconscious priming irrespective of the reward salience of the words. To establish the extent to which the totality of our data provides support for the null hypothesis, namely that a prior inhibitory challenge has no effect on susceptibility to unconscious priming, we combined the two studies in a Bayesian analysis. Specifically, we combined the raw effect sizes of Experiment 1 and 2 weighted by the square of the SE of each estimate and computed a Bayes factor for the combined effect specifying the prior as a uniform distribution from zero to twice the weighted mean of the two control conditions (Weighted M = 2.28). This analysis gave a Bayes Factor of 0.23, providing strong evidence for the null hypothesis, that a highly demanding inhibitory task did not increase susceptibility to unconscious priming.

3.2.4 The Effect of Trait Self-Control and Mental Exhaustion on Unconscious Priming

To evaluate the potential effects of trait self-control and mental exhaustion on unconscious priming the above ANOVA was repeated with SCS and reported task-related mental exhaustion included as covariates. This identified a significant main effect of task-related mental exhaustion, $F(1, 112) = 5.06$, $p = .026$, $\eta_p^2 = .04$, and a significant interaction between task-related mental exhaustion and word type, $F(1, 112) = 10.55$, $p = .002$, $\eta_p^2 = .09$. No significant main effect of SCS was observed, $F(1, 112) = 1.17$, $p = .282$, $\eta_p^2 = .01$, and no significant interaction involving SCS, $F < 1$. Bivariate correlations were used to explore the relationship between task-related mental exhaustion and word type. These revealed a significant positive relationship between task-related mental exhaustion and the percentage of target matches for reward salient words, $r(118) = .26$, $p = .004$, and a non-significant negative relationship between task-related mental exhaustion and the percentage

of target matches for neutral words, r (118) = -.06, p = .550, see Figure 3. Note, this effect is independent of priming.

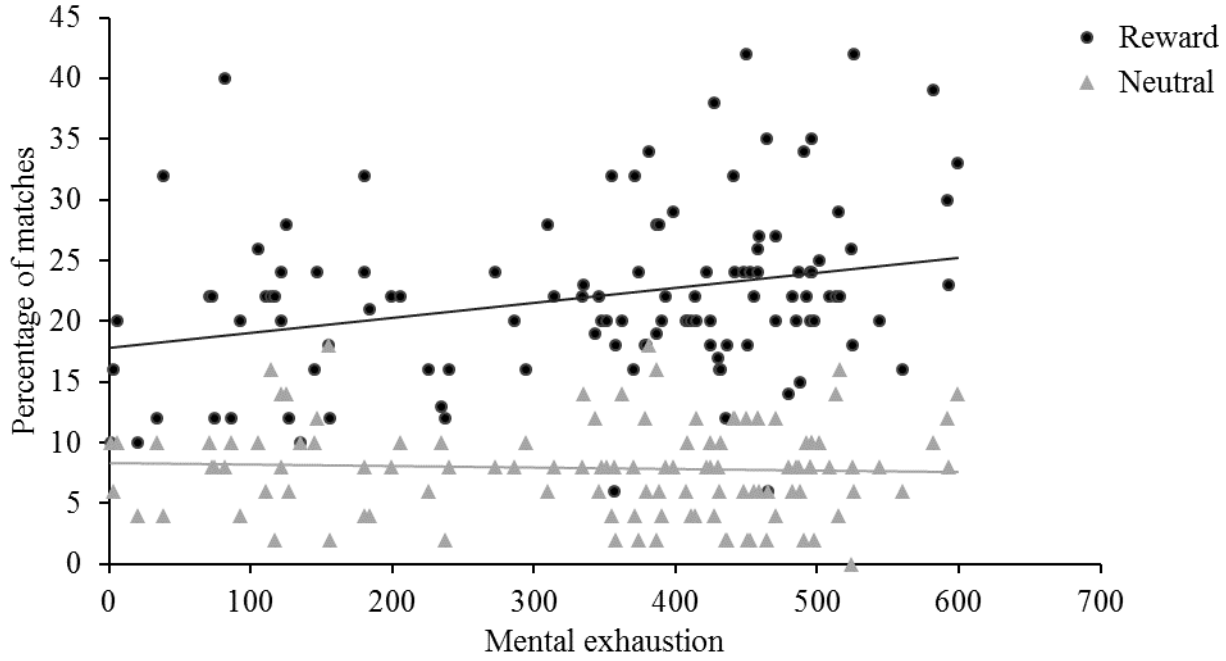

Figure 3. The relationship between reported task-related mental exhaustion and the percentage of stem completions matching reward salient and neutral targets.

3.3 Discussion

Experiment 2 sought to establish whether the failure of a prior inhibitory task to influence susceptibility to unconscious priming, as observed in Experiment 1, would hold true where the primes were reward salient rather than neutral. The stem completion task was again found to be sensitive to unconscious priming. The inhibitory task was also again found to be experienced as significantly more mentally exhausting than the control task. Crucially, consistent with Experiment 1, the prior inhibitory challenge was again found not to influence the degree of susceptibility to unconscious priming, regardless of whether the primes were reward salient or neutral terms. Combining the results of Experiment 1 and 2 in a Bayesian

analysis provided strong support for the null hypothesis, namely that the prior inhibitory challenge did not influence unconscious priming. Similarly, and again consistent with Experiment 1, neither trait self-control nor task-related mental exhaustion were found to significantly influence unconscious priming.

Interestingly, the results revealed a significant positive correlation between how mentally exhausting participants rated the inhibitory task and the number of stems completed with reward salient targets. While this effect could be considered partially consistent with previous research revealing increased approach behaviour and consumption after highly demanding tasks (Hofmann et al., 2007; Vohs & Heatherton, 2000), it was independent of both the inhibitory task and priming conditions and as such is tangential to the objectives of this study.

4. General Discussion

Previous research has examined the effect of challenging inhibitory tasks on a range of conscious behavioural outcomes (e.g. Fischer et al., 2012; Vohs & Faber, 2007; Vohs & Heatherton, 2000), but to date none have directly examined the effects on susceptibility to influences elicited unconsciously. Here, we sought to address this by establishing whether the effects observed in conscious contexts extend to unconscious influences. The present study therefore examined the effect of a prior inhibitory task on subsequent susceptibility to unconscious priming. We manipulated the degree to which an inhibitory task was challenging using two versions of a colour classification task, specifically designed to place differing demands on inhibitory processes and examined subsequent susceptibility to subliminal priming using a stem completion paradigm.

Experiment 1 examined the effect of a challenging inhibitory task on subsequent susceptibility to subliminal priming with neutral words in the stem completion task. Experiment 2 extended Experiment 1 by introducing a systematic difference in word type

permitting the priming effects to be contrasted between reward salient and neutral terms. The stem completion task proved sensitive to unconscious priming in both experiments, with more primes being used as stem completions. The manipulation of inhibitory demands also proved to be effective in both experiments, with the challenging version of the colour classification task being rated as significantly more mentally exhausting. Crucially however, neither experiment revealed a significant interaction between the degree to which the prior task was taxing and subsequent susceptibility to unconscious priming. Combining the two experiments using Bayesian analysis, provided strong evidence for the null hypothesis that the degree of inhibitory control required by the prior task had no effect on subsequent susceptibility to unconscious influences. The results presented here therefore indicate that completing a task requiring high levels of inhibitory control does not influence an individual's subsequent degree of susceptibility to subliminal priming. Additionally, neither how mentally exhausting individuals rated the colour classification task, nor the measure of trait self-control (SCS) were found to correlate with levels of unconscious priming.

Findings from supraliminal priming research (Bertrams et al., 2015) and the self-control literature in general (see Hagger et al., 2010) appear to demonstrate a reliance on automatic bottom-up processing following a taxing inhibitory task. Had the effects from such research extended to unconscious influences, we would have expected to observe greater levels of subliminal priming for those whose inhibitory processes had previously been burdened by the challenging colour classification task. However, our results suggest that this is not the case and instead that the inhibitory nature of the task does not affect subliminal priming. Unconscious influences appear to be independent of fatigue arising from frontal executive processes.

While our central finding differs to the effects commonly observed in the self-control literature, some interesting parallels can otherwise be drawn. Firstly, in the present study, a

significant difference is reported between task conditions, with much higher levels of perceived mental exhaustion being attributed to the challenging versus easy version of the inhibitory task. This is consistent with such inhibitory tasks being used to create a temporary state of mental exhaustion, as has been widely applied in the self-control literature (e.g. Friese, Hofmann, & Wänke, 2008). Secondly, in Experiment 2 those individuals' who rated the colour classification task as more mentally exhausting were found to be significantly more likely to produce reward relevant terms as stem completions. While this correlation does not permit causal conclusions, the observed relationship is consistent with previous research suggesting that where self-control is seemingly reduced individuals exhibit a preference for, and consume more, unhealthy food items (Hofmann et al., 2007; Papies & Hamstra, 2010; Papies et al., 2008; Vohs & Heatherton, 2000).

Given the prevalence of chronically impaired inhibitory control in mood disorders such as anxiety and depression, some reassurance might be taken from our results. The inhibitory challenge common to suffers of such disorders should not, in its own right, result in a greater susceptibility to unconscious influences. However, this can only be concluded within the constraints of the current study which examined only neutral and reward salient primes. Given the established attentional bias towards mood-congruent information in those suffering from depression (Leung, Lee, Yip, Li, & Wong, 2007), stronger conclusions would require our findings to be extended to include stimuli of direct relevance to those mood conditions.

The Bayesian analysis provides certainty that the results represent a sensitive null result rather than reflecting insensitivity. However, future replications might benefit from implementing alternative priming measures with potentially stronger priming effects. Furthermore, while this study rigorously identified participants' subjective threshold of awareness aiming to ensure that the primes were genuinely subliminal, a powerful alternative

would be to apply the Process Dissociation Procedure (PDP, see Jacoby, 1998). Such a procedure would have the advantage of permitting the direct comparison of controlled (conscious) and automatic (unconscious) influences over the stem completions and would be independent of the absolute threshold achieved.

The current study provides strong evidence that neither an extended period of inhibitory control, nor individuals' level of trait self-control, influences subsequent susceptibility to unconscious influences. This provides further evidence of a difference between unconscious cognitive processes and consciously experienced mental demands. Considering the importance of self-control in shaping human behaviour it is reassuring that prior use of inhibitory processes appears not to leave us open to unconscious influences.

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Appendix A: Word stimuli employed in Experiments 1 and 2

Visual Threshold	Stem Completion Study 1		Stem Completion Study 2	
			Reward	*Neutral*
red	shape	debit	bacardi	earlobe
green	stupid	offend	baguette	sanctify
blue	asset	muscle	banana	endure
yellow	talent	bound	barbeque	transpire
orange	morgue	armour	batter	raving
black	appear	goose	berry	goose
grey	deter	wages	biscuit	quarrel
purple	hollow	elect	bread	refer
pink	verify	marry	burger	expire
brown	which	cheese	candy	freak
one	birch	racer	caramel	beehive
two	yeast	cough	cheese	relate
three	vacant	grass	chips	dried
four	glean	orgasm	chocolate	narrative
five	scurry	street	cocoa	wedge
six	ballet	victim	coffee	object
seven	friend	horse	cream	blame
eight	tender	awake	crisps	untidy
nine	salary	behave	croissant	calloused
ten	visit	crash	curry	elect
eleven	native	speed	dessert	rapport
twelve	affair	common	dinner	danger
thirteen	squid	secure	feast	slave
fourteen	triple	clear	flake	debit
fifteen	notice	thump	galaxy	famine
sixteen	relate	emblem	honey	vague
seventeen	patch	change	lager	litre
eighteen	famine	click	lemon	width
nineteen	mutate	metro	lunch	limit
twenty	bride	germs	mango	feral
	panda	endure	martini	pollute
	adorn	sound	melon	hinge
	define	locate	meringue	dismount
	afresh	insert	nougat	wangle
	annoy	threat	orange	native
	single	diary	picnic	triple
	oracle	refer	pudding	vicious
	dried	raisin	raisin	mutate
	trust	estate	roast	venus

aerial	known	salmon	vessel
galaxy	alley	sambuca	offense
expire	alive	sausage	fatigue
risen	guilty	scone	waive
scope	rustle	sherbet	hydrant
cable	trough	sorbet	velour
global	astute	sweets	vacant
garlic	latte	tortilla	abdicate
motive	gentle	truffle	verbose
pasta	admit	vanilla	abiding
raving	drone	waffle	wallow

Appendix B: Word stimuli Experiment 2 with frequency data

Stem	Reward	Frequency	Stem	Neutral	Frequency	Number of Letters
bac	bacardi	23	ear	earlobe	12	7
bag	baguette	19	san	sanctify	13	8
ban	banana	511	end	endure	511	6
bar	barbeque	11	tra	transpire	22	9
bat	batter	148	rav	raving	166	6
ber	berry	461	goo	goose	479	5
bis	biscuit	552	qua	quarrel	552	7
bre	bread	3621	ref	refer	3720	5
bur	burger	210	exp	expire	218	6
can	candy	360	fre	freak	337	5
car	caramel	71	bee	beehive	74	7
che	cheese	2504	rel	relate	2555	6
chi	chips	1789	dri	dried	1730	5
cho	chocolate	1931	nar	narrative	1672	9
coc	cocoa	479	wed	wedge	400	5
cof	coffee	6213	obj	object	6135	6
cre	cream	3099	bla	blame	2973	5
cri	crisps	353	unt	untidy	376	6
cro	croissant	28	cal	calloused	27	9
cur	curry	526	ele	elect	526	5
des	dessert	300	rap	rapport	293	7
din	dinner	5858	dan	danger	5755	6
fea	feast	849	sla	slave	858	5
fla	flake	262	deb	debit	259	5
gal	galaxy	605	fam	famine	633	6
hon	honey	1413	vag	vague	1432	5

lag	lager	497	lit	litre	502	5
lem	lemon	1190	wid	width	1128	5
lun	lunch	4850	lim	limit	4848	5
man	mango	110	fer	feral	119	5
mar	martini	114	pol	pollute	109	7
mel	melon	198	hin	hinge	203	5
mer	meringue	57	dis	dismount	67	8
nou	nougat	10	wan	wangle	18	6
ora	orange	2585	nat	native	2568	6
pic	picnic	632	tri	triple	670	6
pud	pudding	837	vic	vicious	840	7
rai	raisin	29	mut	mutate	27	6
roa	roast	510	ven	venus	510	5
sal	salmon	1403	ves	vessel	1382	6
sam	sambuca	1	off	offense	8	7
sau	sausage	497	fat	fatigue	480	7
sco	scone	145	wai	waive	138	5
she	sherbet	24	hyd	hydrant	14	7
sor	sorbet	34	vel	velour	24	6
swe	sweets	726	vac	vacant	785	6
tor	tortilla	33	abd	abdicate	45	8
tru	truffle	25	ver	verbose	31	7
van	vanilla	176	abi	abiding	196	7
waf	waffle	87	wal	wallow	60	6

Appendix C: Word stimuli Experiment 2 with Alternative Completions

Reward Stimuli				*Neutral Stimuli*			
Stem	Target Word	Alternative Completions		Stem	Target Word	Alternative Completions	
bac	bacardi	backing	backfire	ear	earlobe	early	earnest
bag	baguette	baggage	bagpipe	san	sanctify	sanction	sanctuary
ban	banana	band	bangle	end	endure	endorse	endless
bar	barbeque	barber	barge	tra	transpire	transit	transient
bat	batter	baton	batch	rav	raving	ravage	ravel
ber	berry	beret	bereaved	goo	goose	good	goon
bis	biscuit	bishop	bison	qua	quarrel	quantity	quandary
bre	bread	break	breath	ref	refer	refine	refrigerate
bur	burger	burden	burglar	exp	expire	express	export
can	candy	canal	canary	fre	freak	free	freedom
car	caramel	career	carbon	bee	beehive	beetle	beech
che	cheese	cheek	cheerful	rel	relate	release	relationship
chi	chips	chief	chilly	dri	dried	drive	drily

cho	chocolate	choice	choke	nar	narrative	narrow	narrate
coc	cocoa	cocaine	cocoon	wed	wedge	wedding	Wednesday
cof	coffee	coffin	coffer	obj	object	objective	objector
cre	cream	crease	creep	bla	blame	black	blade
cri	crisps	criminal	cricket	unt	untidy	until	untold
cro	croissant	crocus	crochet	cal	calloused	calendar	calico
cur	curry	current	curtsey	ele	elect	electricity	electrode
des	dessert	despite	desperate	rap	rapport	rapid	rapt
din	dinner	dingy	dinghy	dan	danger	danger	dance
fea	feast	feature	fearful	sla	slave	slang	slap
fla	flake	flag	flair	deb	debit	debris	debate
gal	galaxy	gallant	gallery	fam	famine	fame	familiar
hon	honey	honour	honest	vag	vague	vagrant	vagabond
lag	lager	lagging	lagoon	lit	litre	literal	literacy
lem	lemon	lemming	lemur	wid	width	wide	widen
lun	lunch	lunge	lung	lim	limit	limpet	limp
man	mango	manicure	manager	fer	feral	ferocious	ferment
mar	martini	market	margin	pol	pollute	polio	polite
mel	melon	mellow	melancholy	hin	hinge	hinder	hindsight
mer	meringue	merge	mercury	dis	dismount	disciple	disco
nou	nougat	nourish	noun	wan	wangle	wand	wander
ora	orange	oracle	orator	nat	native	nature	nation
pic	picnic	pictorial	piccolo	tri	triple	tripod	trivial
pud	pudding	puddle	pudgy	vic	vicious	vicar	vicinity
rai	raisin	rain	raise	mut	mutate	mutilate	mutation
roa	roast	roam	road	ven	venus	veneer	venal
sal	salmon	salary	saliva	ves	vessel	vestige	vestry
sam	sambuca	sample	samaritan	off	offense	offend	offensive
sau	sausage	sauna	saunter	fat	fatigue	fate	fatality
sco	scone	scold	score	wai	waive	wail	waif
she	sherbet	shed	sheath	hyd	hydrant	hydraulic	hydrangea
sor	sorbet	sorrow	sort	vel	velour	velvet	velocity
swe	sweets	swede	sweep	vac	vacant	vacate	vacuum
tor	tortilla	torture	torso	abd	abdicate	abduct	abdomen
tru	truffle	trudge	trumpet	ver	verbose	verbatim	verb
van	vanilla	vandal	vanity	abi	abiding	ability	abide
waf	waffles	wafer	waft	wal	wallow	wallet	wallaby